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Original Article

Radiology Section

Evaluation of Spinopelvic Parameters in Patients with Different Grades of Intervertebral Disc Degeneration in Lumbosacral Spine vs Normal Asymptomatic Population: A Retrospective Observational Study

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ABSTRACT

Introduction: Spinopelvic malalignment causes continual backache. Intervertebral Disc Degeneration (IDD) is a leading cause of low backache. Understanding the relationship between spinopelvic parameters and IDD can help with better diagnosis and treatment and avoid unnecessary investigations.

Aim: To measure radiographic spinopelvic parameters of patients diagnosed with varying grades of IDD in the lumbosacral spine on Magnetic Resonance Imaging (MRI), and to compare them with radiographs of the asymptomatic population (controls).

Materials and Methods: A hospital-based retrospective observational study was done from January 2021 to August 2022 at a tertiary care hospital in Uttar Pradesh, India with 80 patients diagnosed with IDD on MRI and 80 controls. Cases were defined as patients diagnosed to have IDD on MRI and controls were those individuals who did not have disc degeneration on MRI. Lateral lumbosacral spine radiographs were taken, and spinopelvic parameters {Pelvic Tilt (PT), Sacral Slope (SS), Pelvic Incidence (PI), Lumbar Lordosis (LL), lumbo-sacral angle, and sacral horizontal angle} were measured using Surgimap Spine Software. T-test and Chi-square test were used for comparison between cases and controls.

Results: Six patients had asymmetric disc bulge, 11 had symmetric disc bulge, 18 had disc extrusion and 45 had disc protrusion. Mean PT in patients with IDD was 11.05±3.84°, and control was 8.65±3.19°, p-value=0.009. Mean SS in case group was 38.38±3.03° and control was 36.56±3.43°, p-value=0.031. The mean PI of cases was 49.44±8.39° and control 46.19±9.01°, p-value=0.02. LL angle was higher in IDD at 46.34°, and was 45.36° in healthy individuals, without statistically significant difference. The mean lumbo-sacral angle in both study groups was similar. The mean Sacral Inclination Angle (SIA) was found to be 43.99° and 44.96° in the case and control group respectively without showing significant differences. A statistically significant difference was found only for the comparison of PT between different grades of IDD (p-value=0.039).

Conclusion: Using Surgimap Spine Software, one can predict the individuals that possess a greater propensity of developing degeneration of disc and chronic low back pain in a more cost-effective manner.

Keywords: Intervertebral disc displacement, Low back pain, Spine, Magnetic resonance imaging, X-rays

INTRODUCTION

Spinopelvic malalignment can cause continual backache since an individual's sacropelvic orientation reflects their unique anatomical make-up. IDD is a leading cause of low back pain [1]. Sarla G described that while 70-90% individuals experience low backache, IDD occurred in 26.9% which then presents with radiculopathy along with backache [2]. Spinopelvic parameters have been extensively studied in the normal population, but the literature lacks significance in describing their relationship with IDD [3-7]. Measuring spinopelvic parameters on radiographs can help to predict, if a patient needs MRI, hence avoiding unnecessary expenses and delays in diagnosis [7]. A lot of studies have been done to describe the spinopelvic parameters in normal populations but the literature lacks significance in describing their relationship with IDD [3-6]. Over the past few years, increased emphasis has been placed on the preservation of spinal-sagittal alignment to accomplish optimum postoperative results [7]. Many studies have reported significance of these spinopelvic parameters in normal functioning and balance of spine, and diseases of spine [3-6]. Analysis of spinopelvic parameters is hence of critical importance to optimise the management of degenerative diseases of disc [8]. Present study results have the potential to aid in cost-effective, early detection of those at risk for disc degeneration. With this background, the present study was conducted with the aim to measure radiographic spinopelvic parameters of patients diagnosed with varying grades of IDD in lumbosacral spine on MRI, and to compare them with radiographs of controls.

MATERIALS AND METHODS

A hospital-based retrospective observational study was conducted in Teerthanker Mahaveer Medical College and Research Centre, Moradabad, Uttar Pradesh, India from January 2021 to August 2022. Institutional Ethics Committee (IEC) (Ref no. TMU/IEC/20-21/042) approval was obtained. Written informed consents were taken from participants.

This research included data of 80 individuals between the age of 18-80 years who were diagnosed with IDD on MRI.

Inclusion criteria: Patients with chronic low backache, diagnosed to have IDD on MRI were included in the study. The age range for cases were 18-65 years and controls were 18-55 years.

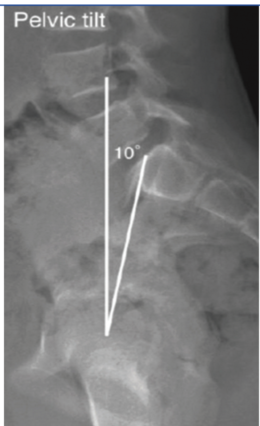
Exclusion criteria: Patients who had spinal trauma/infection, spondylolisthesis, spinal deformities, refused consent, spinal surgery, pregnant women were excluded from the study.

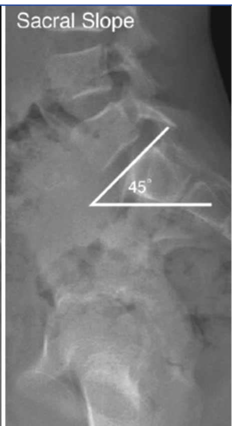
Procedure

MRI was done on a 1.5T 16-Channel machine (Siemens' Magnetom Avanto Tim+Dot system, Siemens, Germany). It was determined that the patient had IDD by performing an MRI of the lumbosacral spine using axial and sagittal T1W and T2W sequences. IDD was graded as symmetric disc bulge, asymmetric disc bulge, disc protrusion and disc extrusion [9]. Lateral radiographs of the lumbosacral spine with coverage from upper border of T12 vertebra till mid-thigh were taken, with the patient in supine position and exposure factors of 75 kV and 45 mAs on RADSPEED 80 Fixed Radiography Machine, Shimandzu Corporation. Authors had used Surgimap Spine Software to analyse patient's lateral lumbosacral radiographs and quantify spinopelvic parameters after grading IDD. It is a free computer software which creates spine related metrics for surgery planning [Table/Fig-1]. Following six spinopelvic parameters were measured [8]:

1. **Pelvic Tilt (PT)-** Angle between the line joining hip axis (midpoint of bicoxofemoral axis) and centre of S1 endplate and reference vertical line [Table/Fig-2].
2. **Sacral Slope (SS)-** Angle between line drawn along endplate of sacrum and horizontal reference line extended from posterior superior corner of S1 [Table/Fig-3].
3. **Pelvic Incidence (PI)-** Angle between line extending from centre point of bicoxofemoral axis to midpoint of superior endplate of S1 vertebral body and a line perpendicular to superior endplate of S1 vertebral body [Table/Fig-4].
4. **Lumbar Lordosis Angle (LLA)-** Angle between cephalad endplate of first lumbar vertebra and cephalad endplate of sacrum [Table/Fig-5].
5. **Lumbosacral angle (LSA)-** Angle between line along the upper border of sacrum and lower border of L5 [Table/Fig-6].
6. Sacral Inclination Angle (SIA)- Angle between line along posterior border of S1 body and reference vertical line [Table/Fig-7].

[Table/Fig-1]: Image of Surgimap Spine Software showing the measurement of all six variables.

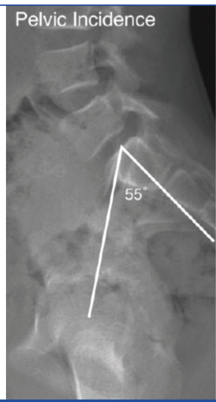


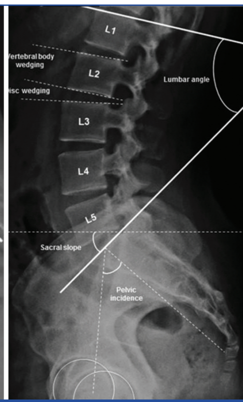


[Table/Fig-2]: Measurement of Pelvic Tilt (PT).
[Table/Fig-3]: Measurement of Sacral Slope (SS). (Images from left to right)

IDD is graded as [9,10]:

1. **Symmetric bulging disc:** Symmetrical presence of disc tissue circumferentially (50-100%) beyond the edges of ring apophyses.





[Table/Fig-4]: Measurement of Pelvic Incidence (PI).
[Table/Fig-5]: Measurement of Lumbar Lordosis angle (LLA). (Images from left to right)

[Table/Fig-6]: Measurement of Lumbosacral angle.
[Table/Fig-7]: Measurement of Sacral Inclination Angle (SIA).
(Images from left to right)

2. **Asymmetric bulging disc:** Asymmetrical bulging of disc margin (50-100%).
3. **Protrusion:** Focal abnormalities of disc margin involving <25% of disc circumference with distance between edges of disc material beyond the disc space less than the distance between edges of the base.
4. **Extrusion:** In atleast one plane, any one distance between the edges of disc material beyond disc space is greater than the distance between edges of the base measured in same plane.

STATISTICAL ANALYSIS

Statistical analysis was performed based on each group's mean and Standard Deviation (SD) using Statistical Package for the Social Sciences (SPSS) software version 24.0. T-test and Chi-square test were used for analysis between cases and controls. Analysis of Variance (ANOVA) was used to compare the pelvic parameters between different grades of IDD in cases. Statistical level of significance was fixed at p-value <0.05.

RESULTS

The mean age of cases was higher as compared to controls [Table/Fig-8].

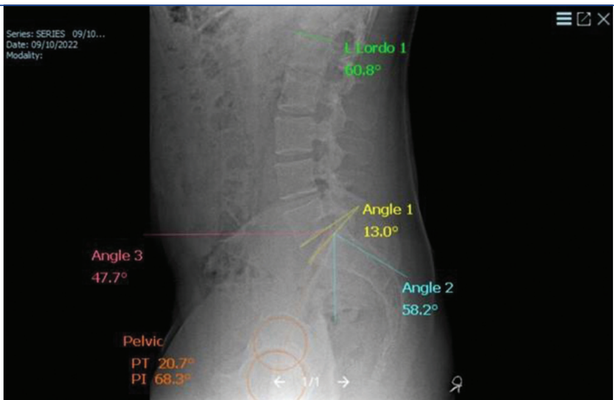
Age group (in years)	Cases		Controls		Chi-square test, p-value
	Male	Female	Male	Female	
10-20	1	1	14	4	
21-30	16	4	25	23	
31-40	8	12	3	8	
41-50	6	10	1	1	0.10, 0.05
51-60	6	7	1	0	
61-70	5	4	0	0	
71-80	0	0	0	0	
Mean±SD	41.7±4.7		25.6±8.7		

[Table/Fig-8]: Mean age of total study subjects and of cases and controls Chi-square.

IDD grades among study groups: Disc was considered normal if nucleus pulposus was seen within the normal boundaries of the annulus fibrosus without evidence of any disc material beyond margins of ring apophyses [Table/Fig-9-11]. In case group, IDD grades were classified into symmetric disc bulge, asymmetric disc bulge, disc protrusion [Table/Fig-12-14] and disc extrusion [Table/Fig-15-17]. Asymmetric disc bulge was found in six cases, symmetric disc bulge was found in 11 cases, disc extrusion was seen in 18 cases and disc protrusion in 45 cases [Table/Fig-18].

[Table/Fig-9]: Sagittal T2W MRI of control- No posterior disc bulge, annular tear, or spinal canal stenosis. Vertebral body heights are well-maintained and posterior elements appear normal. There is no bone marrow oedema/bony lesion. All lumbar intervertebral discs appear normal.

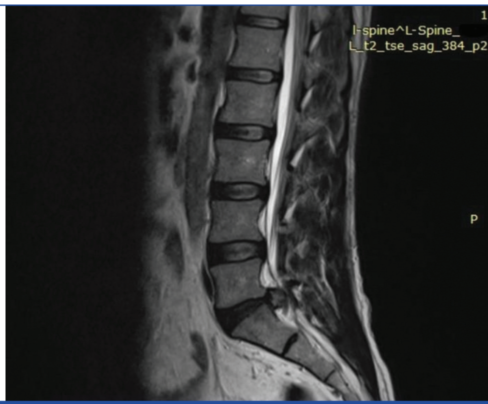
[Table/Fig-10]: Axial T2W MRI of control at L4-L5 intervertebral disc- No posterior disc bulge, annular tear, disc protrusion, spinal canal stenosis, or neural foraminal narrowing. L4-L5 intervertebral disc appears normal in signal intensity.



[Table/Fig-11]: Lateral X-Ray Lumbosacral Spine of same case as [Table/Fig-9,10]- Angles measured using Surgimap Spine Software. PT: Pelvic Tilt; PI: Pelvic Incidence; L: Lordo 1=Lumbar Lordosis Angle; Angle 1: Lumbosacral Angle; Angle 2: Sacral Inclination Angle, Angle 3: Sacral Slope.

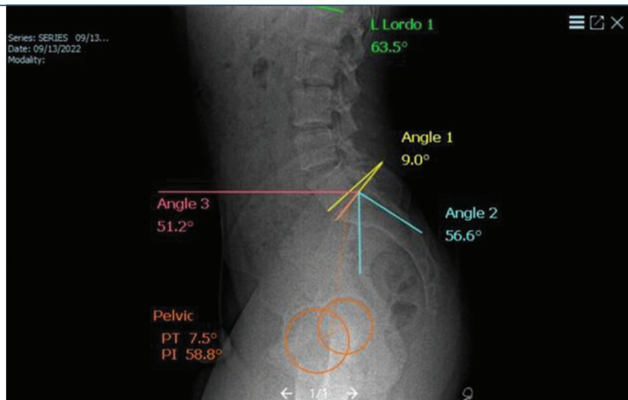
Mean Pelvic Tilt (PT): It was significantly higher in cases vs controls.

Mean Sacral Slope (SS) among study groups: Mean SS in cases was 38.38° (18.0° to 53.4°, CI=95%). Average SS in control group was 36.56° (20.6° to 55.5°, CI=95%). Cases demonstrated higher values than controls [Table/Fig-19].



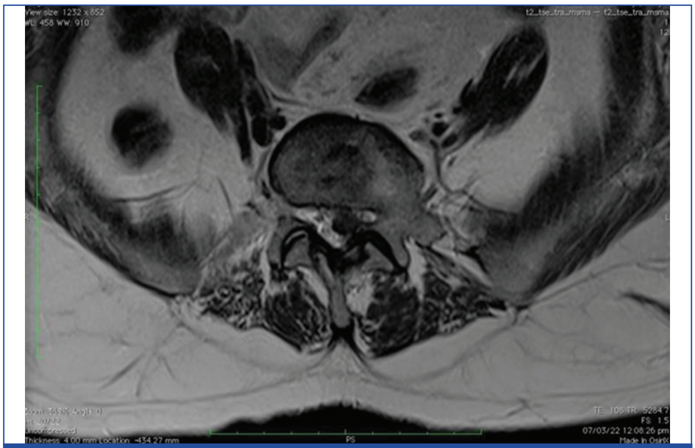
[Table/Fig-12]: Sagittal T2W MRI of protrusion- Posterocentral disc protrusion at L5-S1 intervertebral disc level, causing significant indentation over anterior thecal sac. Disc dehydrative changes seen at this level.

[Table/Fig-13]: T2W Axial image of protrusion at L5-S1 level- Posterocentral and left paracentral disc protrusions indentating over anterior thecal sac, causing narrowing of left lateral recess and neural foramen, compressing over nerve roots. AP canal diameter 4.3 mm.

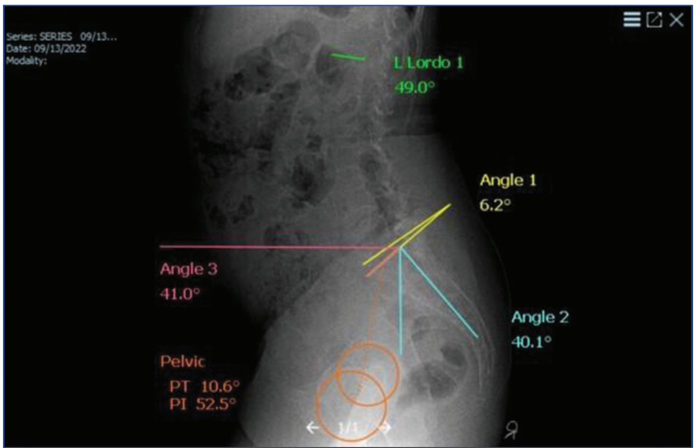


[Table/Fig-14]: Lateral X-Ray Lumbosacral Spine of same case as [Table/Fig-12,13] Angles measured using Surgimap Spine Software. PT: Pelvic Tilt; PI: Pelvic Incidence; L: Lordo 1=Lumbar Lordosis Angle; Angle 1: Lumbosacral Angle; Angle 2: Sacral Inclination Angle; Angle 3: Sacral Slope.

[Table/Fig-15]: Sagittal T2W MRI of extrusion- Disc desiccation changes at L5-S1 intervertebral disc level with reduction of corresponding disc height. Type II Modic changes seen involving inferior endplate of L5 and superior endplate of S1. Posterior disc bulge with extrusion, caudal migration at this level indenting over anterior thecal sac.



[Table/Fig-16]: T2W Axial image of extrusion at L5-S1 level- disc bulge with posterocentral disc extrusion, mild caudal migration, bilateral ligamentum flavum hypertrophy, facetal arthropathy (left >right), indenting over anterior thecal sac, causing narrowing of left lateral recess and neural foramen, compressing over left nerve roots. AP canal diameter 3.0 mm.



[Table/Fig-17]: Lateral X-ray Lumbosacral Spine of same case as [Table/Fig-15,16]- Angles measured using Surgimap Spine Software. PT: Pelvic Tilt; PI: Pelvic Incidence; L: Lordo; 1=Lumbar Lordosis Angle: Angle 1: Lumbosacral Angle; Angle 2: Sacral Inclination Angle; Angle 3: Sacral Slope.

IDD Grade	Case		Control		Chi-square	p-value
	N	%	N	%		
Normal	0	0	80	100	74.87	<0.01*
Asymmetric disc bulge	6	7.5	0	0		
Symmetric disc bulge	11	13.8	0	0		
Extrusion	18	22.5	0	0		
Protrusion	45	56.2	0	0		

[Table/Fig-18]: Comparison of IDD grade among the study groups.
*Statistically significant, IDD: Intervertebral Disc Degeneration; N: Number of patients; %: Percentage of patients

Spinopelvic parameter	Angles in cases (°)	Angles in controls (°)	p-value
	Mean±SD	Mean±SD	
Pelvic Tilt	11.05±3.84	8.65±3.19	0.009*
Sacral Slope	38.38±3.03	36.56±3.43	0.031*
Pelvic Inclination	49.44±8.39	46.19±9.01	0.020*
Lumbar Lordosis	46.34±10.34	45.36±8.84	0.520
Lumbosacral Angle	14.55±6.21	14.58±4.65	0.980
Sacral Inclination Angle (SIA)	43.99±8.41	44.96±9.23	0.490

[Table/Fig-19]: Comparison of mean spinopelvic parameters in cases and controls.
*Statistically significant, SD: Standard deviation

Mean PI in cases was 49.44±8.39° which was statistically significant (0.02). Sum of average SS and average PT in case group (38.38+11.05=49.43) was equal to mean PI, i.e., 49.44, hence, proving that the correlation "PI=SS+PT" stands true in present study results.

Statistically significant difference was found only for comparison of PT between different grades of IDD. PT was found more in disc extrusion followed by disc protrusion, asymmetric disc bulge and symmetric disc bulge cases with p-value 0.039 [Table/Fig-20].

IDD grade		Pelvic Tilt (PT)	Pelvic Incidence (PI)	Sacral slope	Lumbar lordosis angle	Lumbo-sacral angle	Sacral inclination angle (SIA)
Asymmetric disc bulge	Mean ± SD	11.33 ± 3.615	48.17 ± 9.020	36.83 ± 11.635	43.33 ± 12.987	11.00 ± 4.940	45.17 ± 12.545
Extrusion	Mean ± SD	12.06 ± 2.729	48.22 ± 9.397	36.28 ± 8.608	43.06 ± 11.227	13.89 ± 5.989	40.11 ± 7.372
Protrusion	Mean ± SD	11.40 ± 3.593	50.07 ± 8.601	38.62 ± 7.331	46.96 ± 10.059	14.49 ± 6.683	45.04 ± 7.507
Symmetric disc bulge	Mean ± SD	7.82 ± 2.111	49.55 ± 5.956	41.64 ± 7.646	50.82 ± 7.236	17.82 ± 3.894	45.36 ± 10.230
ANOVA test		3.75	0.25	1.11	1.55	1.79	1.69
p-value		0.039*	0.86	0.35	0.21	0.16	0.18

[Table/Fig-20]: Association of various angles according to IDD grade among cases.
*Statistically significant, IDD: Intervertebral disc degeneration; SD: Standard deviation

DISCUSSION

Sacropelvic morphology describes the anatomy or shape of pelvis that is specific to an individual, while sacropelvic orientation is reliant upon position of the individual and hence, is variable. Mainly, four spinopelvic parameters are required for evaluation of the spinopelvic balance: PI, PT, SS and LL [11]. Substantial study has been done to demonstrate a relationship between orientation of the pelvis regarding spine and between these spinopelvic characteristics and degenerative disorders of the lumbosacral spine. Several spinopelvic parameters were specified after extensive research by Duval-Beaupere G et al., [12].

Pelvic Tilt (PT): When PT was compared in case and control group, this difference was found to be statistically significant. Singh R et al., found that mean PT in normal population was 9.30±7.16°, which was like that found in present study [8]. Chaleat-Valayer E et al., found the mean PT in patients with chronic low backache as 14.3° and 13.6° in women and men respectively, which was in a similar range as the cases of present study [13]. Another study by Poonia A et al., found mean PT in patients with lumbar disc herniation as 13.52±5.84°, again in similar range as our cases [14]. In a study by Borkar SA et al., mean PT in patients with prolapsed lumbar disc was 23.35±14.03°, which was significantly higher when compared with controls (mean PT 14.3±4.08°, p<0.001) [15]. Findings of Borkar SA et al., although concordant with present study, mean PT in control group was lower in present study compared to theirs.

Sacral Slope (SS): When compared using t-test, mean SS of cases was found statistically significantly higher than asymptomatic individuals. Borkar SA et al., did not find any significant difference with respect to SS, which was incongruous with present study [15]. This is likely because of difference in study populations in both the studies as they included patients with spondylolisthesis and postoperative cases which were excluded in present study.

Pelvic Incidence (PI): Mean PI was more in cases (49.44±8.39°) as compared to controls (46.19±9.01°) in present study, which showed significant difference. Similarly, Borkar SA et al., showed that mean PI in patients of chronic low backache was 53.96±9.47° and in patients with lumbar disc prolapse was 59.4±21.33°, which were both significantly higher when compared with asymptomatic individuals (49.29±5.95°, p<0.001) [15]. There findings were congruent with present study.

After puberty, PI is a stable morphological measure that is unaffected by changes in body posture [16-18]. PI is calculated by adding PT to SS, both of which can be different. Patients with IDD had greater mean PT and SS than controls. Hence, when compared to asymptomatic controls, their aggregate, PI, was also greater.

Increased PI, SS, and LL are all linked to pathophysiology and progression of degenerative alterations of spine, according to earlier research [16-18].

Findings of Lim J and Kim S, which are consistent with present study, concluded that incidence of pelvic symptoms of individuals who had lumbar spondylolisthesis was much higher as compared to asymptomatic individuals [19]. Not only did PI differ significantly between asymptomatic people and people with lumbar spine diseases, so did PT.

Lumbar Lordosis (LL) Angle: Connection between paraspinal muscular spasms and decreased lordotic curve is not extensively validated in literature, despite their frequent usage as a clinical indicator in diagnosis of hypolordosis [20]. Correlation between low back discomfort and lordosis range has yielded conflicting results in literature. Hansson T et al., found that range of lordosis did not vary between asymptomatic individuals and patients with low backache [21]. Murrie VL et al., found that decreased LL was a very weak clinical sign for low backache [22]. Present study found no statistically significant change in LL angle between the patients controls. However, Latimer J et al., found that patients with low backache had significantly more stiffness than those that had no pain [23].

Lumbosacral Angle: Mean lumbosacral angle of asymptomatic patients did not show any statistically significant difference in comparison to patients who had IDD. Chaleat-Valayer E et al., found that average lumbosacral angle was significantly smaller among asymptomatic individuals than patients presenting with chronic low backache, which was incongruent to present study [24].

Sacral Inclination Angle (SIA): Mean SIA in present study was slightly higher in asymptomatic individuals, though statistically insignificant. In their study, Singh R et al., showed that lumbar-lordosis angle had a positive correlation with SIA [8]. While the exact reason behind this incongruency is not known, one of the contributing factors could be subjectivity of Surgimap Spine Software where these angles are measured manually.

Spinopelvic parameters according to IDD grade among cases: Difference between all the measured angles were found to be statistically insignificant in all grades of IDD among the case group except PT.

Glassman SD et al., showed that sagittal balancing parameter calculations are useful for assessing patients with backache complaints and for predicting success of surgery [25]. Pathophysiological mechanism behind disc diseases of lumbar spine can be better understood with spinopelvic parameters, which aid in comprehension of biomechanical stress across lumbosacral junction.

These results have the potential to aid in cost effective, early detection of those at risk for disc degeneration. Those at danger for development of pain in lower backs may also benefit from our efforts to discover and develop novel therapeutics and rehabilitative approaches. More extensive and randomised studies are needed to draw firm conclusions that could aid in lessening the prevalence of low backpain in general population. To the authors' knowledge, this is among few studies which have attempted to assess different spinopelvic parameters according to different grades of IDD of lumbosacral spine.

Limitation(s)

1. This study being a retrospective observational study, authors were unable to determine any causative correlations between disc degeneration and spinopelvic characteristics. It is unknown if the control group patients in present study, who may aid in detecting individuals more likely for developing pain in their backs, will acquire disc degeneration over time because they were not observed for many years. To properly evaluate connection between causes and effects, a long-term study is ideal.
2. Angles were drawn manually in Surgimap Spine Software after which the software generates values in degrees. Some amount of human error is expected when drawing angles on Radiographs. Further studies with multiple observers and good interobserver agreement are required to eliminate this discrepancy, albeit small.

CONCLUSION(S)

When PI, SS, and LL- the angles that define lumbosacral sagittal alignments fluctuate, a patient's likelihood to develop L-spine IDD changes rises. Using Surgimap Spine Software, one can predict the individuals that possess a greater propensity of developing degeneration of disc and chronic low back pain in a more cost-effective manner. Radiography has the potential to be used as a screening tool, especially in low-resource setting and develop novel therapeutics and rehabilitative approaches.

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